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Economic and Environmental Feasibility of a Perennial Cow Dairy Farm

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ABSTRACT

More efficient and economical production systems are needed to improve the sustainability of dairy farms. One concept to consider is using perennial cows. Perennial cows are those that maintain a relatively high milk production for ≥2 yr without going through the typical dry period followed by calving. Farm records show that some cows have produced over 20 kg/d after 4 yr of continuous lactation. A farm simulation model was used to evaluate the long-term performance, environmental impact, and economics of a conceptual perennial cow production system on a typical dairy farm in Pennsylvania. Compared with a traditional 100-cow farm with replacement heifers produced on the farm, a perennial herd of 100 cows and purchased replacements provided environmental benefit but sustained a substantial economic loss. However, increasing the perennial herd to 128 cows better utilized the feed produced on the farm. Compared with the traditional 100-cow farm, use of the perennial 128-cow herd reduced supplemental protein and mineral feed purchases by 38%, increased annual milk sales by 21%, reduced nitrogen losses by 17%, maintained a phosphorus balance, and increased annual net return to farm management by $3200. A traditional 120-cow dairy farm with purchased replacements also used a similar amount of farm-produced feed. Compared with this option, the farm with 128 perennial cows reduced protein and mineral feed purchases by 36%, maintained similar annual milk sales, increased manure production by 7%, reduced N losses by 10%, and increased annual net return by $12,700. The economic feasibility of the perennial-cow dairy farm was very sensitive to the milk production maintained by the perennial herd and market prices for milk and perennial replacement animals. The analysis was relatively insensitive to the assumed useful life of perennial cows as long as they could be maintained in the herd for at least 3 yr. Thus, a perennial cow production system can improve the economic and environmental sustainability of a traditional dairy farm if a similar level in annual milk production per cow can be maintained.
(**Key words:** extended lactation, farm simulation, economics, environment)

INTRODUCTION

Economic and political forces are prompting changes in the dairy industry. Milk prices are adjusting to a global market providing a lower price than that traditionally received in the United States. Political pressures also are directing dairy farms toward better stewardship of land and environmental resources. Management plans and new technology must be implemented to more effectively use manure nutrients and reduce their loss to the environment. Thus, new ideas are being explored to improve the efficiency and profitability of dairy farms while reducing potential adverse effects on the environment.

A possible approach for some farms may be the use of perennial dairy cows. A perennial cow is defined as one that remains at a relatively high milk production level for at least 2 yr without cycling through a dry period and calving. Thus, the animal is bred once to calve at about 2 yr of age. The cow begins lactation at calving, with milk production increasing to a maximum within several weeks thereafter. Production then slowly declines, providing an average of 25 kg/d or more for a lactation potentially extending 2 to 4 yr or beyond. Cows usually follow this production cycle due to a failure in rebreeding. They are not well matched to systems on today's dairy farms, where cows are rebred on approximately an annual basis to stimulate greater annual milk production. The potential exists to develop this type of animal to create full herds on a perennial lactation management plan.

With this possibility in mind, there is a need to determine how this management change would affect the profitability and environmental sustainability of typical dairy farms. Many issues must be considered. Dairy farms are complex systems with many components to manage, from feed production to manure management

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Table 1. Milk production and pregnancy records for cows with lactation lengths of greater than 700 d.[1]

Years in production ±60 d	Days in production	Number of cows	Cows pregnant (%)	Avg. time in milk (d)	Total production (kg)	Average production (kg/d)	Last test production (kg/d)	Last test SCC[2] (×1000 cells/mL)
2.0	700 to 790	2110	33	738	21,320	28.9	20.2	398
2.5	853 to 973	848	24	908	25,399	28.0	20.7	421
3.0	1035 to 1155	129	18	1075	30,474	28.3	20.5	399
3.5	1218 to 1338	74	8	1277	35,769	28.0	22.4	422
4.0	1400 to 1520	26	4	1449	39,032	26.9	21.6	465

[1]Obtained from a national database of DHI Computing Service, Inc. for 852,000 cows in production in the midsummer of 2003. Animals within these periods include 75% of the 4259 cows found with lactation lengths of 700 d or more.

[2]Somatic cell count at last test date; SCC data are from an expanded database of DHI Computing Service, Inc. (Provo, UT) collected from March 2003 through April 2005.

and herd health. Many of these components interact with weather and each other, so that a change in one part of the farm may cause changes throughout other farm components. To properly assess the impacts of a management change, such as the use of a perennial lactating herd, a comprehensive evaluation of the whole farm is needed.

The dairy option of the Integrated Farm System Model provides a tool for performing such an evaluation. Formerly known as the Dairy Forage System Model, or DAFOSYM, this farm simulation model is specifically designed to evaluate production alternatives (Rotz et al., 1999a,b). By simulating several production systems for the same base farm and weather, the long-term performance, environmental impact, and economics can be compared. The information generated guides dairy producers to better-informed decisions as they explore new management options.

The objective of this work was to evaluate the long-term economic and environmental feasibility of a dairy farm when using a perennial lactation management strategy. Specifically, the Integrated Farm System Model was used to determine the effects of this management change on feed use, milk production, manure nutrient cycling and loss, production costs, and estimated net returns for a typical, representative dairy farm in central Pennsylvania.

MATERIALS AND METHODS

Evidence of Perennial Production

Although the concept of a dairy farm with a perennial lactating herd is hypothetical at this time, animals with this production potential are found in our herds today. A search of the national records from DHI Computing Service, Inc. (Provo, UT) was conducted over all cows in production in midsummer 2003. Valid records were found for 4259 cows (0.5% of total records) whose current production equaled or exceeded 700 d of continuous lactation. The longest lactation was 3897 d, producing a total of 84,350 kg of milk with a production of 27 kg on the cow's last test day. Production information for the animals with lactations of 2 to 4 yr in length is summarized in Table 1. These data indicate that average milk production per day of lactation remains relatively constant for cows with greater than 2 yr of extended lactation.

Twenty-six cows in the database had 4 yr (1460 ± 60 d) of continuous lactation (Table 1). The average annual production for this selected group was 9758 kg, with an average 4-yr total production of 39,032 kg (Table 2). This population of 26 cows ranged in average annual production from 3697 to 13,422 kg. Although this is a very small portion of the animals tested, these data indicate that the potential exists for developing herds of perennial lactating cows. To justify further consideration of this concept, an evaluation of the economic and environmental sustainability of this production strategy is needed.

The Integrated Farm System Model

The Integrated Farm System Model simulates the many biological and physical processes of a crop, beef, or dairy farm (Rotz et al., 1999b; Rotz and Coiner, 2003). Crop production, feed use, and the return of manure nutrients back to the land are simulated over many years of weather. Growth and development of alfalfa, grass, corn, soybean, and small grain crops are predicted on a daily time step based on soil and weather conditions. Tillage, planting, harvest, and storage operations are simulated to predict resource use, timeliness of operations, crop losses, and nutritive changes in feeds. Feed allocation and animal response are related to the nutritive value of available feeds and the nutrient requirements of the animal groups making up the herd (Rotz et al., 1999a), where nutrient requirements are determined using the Cornell Net Carbohydrate and Protein System (Fox et al., 2004).

Nutrient flows through the farm are modeled to predict potential nutrient accumulation in soil and loss to

Table 2. Milk production records for 26 cows with 4 yr (±60 d) of continuous lactation[1].

Breed	Days in milk	Parity	Total milk, kg	Average annual milk, kg	Last test date milk, kg	Open or pregnancy status	Last breeding date	Test date
Holstein	1504	1	38,157	9539	13.2		2/15/03	8/05/03
Holstein	1504	1	32,591	8148	18.9		7/02/03	7/14/03
Holstein	1498	1	32,827	8207	24.3[2]	O	12/1/00	7/14/03
Holstein	1496	1	43,019	10,755	11.5			4/22/03
Jersey	1494	1	22,099	5525	9.1	O		3/18/03
Holstein	1489	1	43,927	10,982	24.5[2]		1/10/01	8/12/03
Holstein	1488	4	24,472	6118	6.8			8/15/03
Holstein	1474	5	44,403	11,101	21.4[2]	O	9/27/01	7/28/03
Holstein	1467	3	37,939	9485	21.9[2]	O		7/26/03
Holstein	1464	4	39,799	9950	25.2[2]		9/23/02	7/11/03
Holstein	1459	1	50,341	12,585	22.7[2]	O	1/13/02	8/22/03
Holstein	1456	1	52,273	13,068	17.2	P	1/29/03	8/07/03
Holstein	1445	1	49,665	12,416	29.2[2]	O	8/12/01	8/01/03
Holstein	1435	1	38,955	9739	18.6	O	2/07/03	8/07/03
Holstein	1429	1	42,861	10,715	47.3[2]	O	6/20/03	7/14/03
Holstein	1428	1	36,329	9082	23.6[2]		3/27/02	8/11/03
Holstein	1427	1	14,787	3697	12.0		4/12/03[3]	3/28/03
Holstein	1422	1	41,944	10,486	29.9[2]	O	7/24/00	8/14/03
Holstein	1417	3	53,688	13,422	30.1[2]		8/01/03[3]	7/16/03
Holstein	1416	1	32,237	8060	13.8			8/14/03
Holstein	1414	1	33,902	8476	19.5[2]	O	1/18/00	7/31/03
Holstein	1413	1	40,833	10,208	10.4		3/10/03	7/24/03
Holstein	1413	1	48,803	12,201	34.1[2]	O		7/30/03
Holstein	1412	1	31,176	7794	20.3[2]	O	11/9/01	7/14/03
Holstein	1409	2	47,646	11,912	24.0[2]			7/31/03
Holstein	1407	3	40,171	10,043	32.7[2]	O	1/10/01	7/28/03
Average	1449		39,032	9758	21.6			

[1]Obtained from a national database of DHI Computing Service, Inc. (Provo, UT) for 852,000 cows in production in the mid-summer of 2003. A total of 4259 valid records were found for cows whose current record of production equaled or exceeded 700 d of continuous lactation with 43 cows exceeding 1460 d. For the 26 cows between 1400 and 1520 d of continuous lactation, 1 herd had 4 cows; all others came from separate farms.

[2]Top 16 producing cows on last test date.

[3]Due to reporting procedures to DHI Computing Service, Inc., last breeding date can be after the last test date shown.

the environment (Rotz and Coiner, 2003). The quantity and nutrient content of the manure produced is a function of the quantity and nutrient content of the feeds consumed. Nitrogen volatilization occurs in the barn, during storage, and between field application and soil incorporation as influenced by weather and manure management practices. Denitrification and leaching losses from the soil are related to the rate of moisture movement and drainage from the soil profile as influenced by soil properties, rainfall, and the amount and timing of manure and fertilizer applications. A whole-farm balance of N, P, and K includes the importation of nutrients in feed and fertilizer and the exportation in milk and animals. Supplemental P and K fed, if needed, is the difference between the requirement of the animal group (Fox et al., 2004) and the sum of that contained in the feeds consumed.

Simulated performance is used to predict production costs, income, and the net return of the farm for each weather year (Rotz and Coiner, 2003). A whole-farm budget is used where investments in equipment and structures are depreciated over their economic life. The resulting annual costs are summed with annual expenditures for resources and products used to obtain a total production cost. This total cost is subtracted from incomes for farm produce sold to determine an annual net return to management. By modeling several alternatives, the effects of system changes are compared, including resource use, production efficiency, environmental impact, and net return. The distribution of annual values obtained is used to assess the risk involved in alternative strategies as weather conditions vary.

Farm Description and Management Scenarios

To evaluate the concept of a perennial cow dairy farm, 5 animal management scenarios were compared on a representative farm. Each farm scenario was modeled as an established production system (i.e., the transition from one scenario to another was not considered).

Table 3. Important economic parameters and prices assumed for various system inputs and outputs for the analysis of the representative dairy farms. Prices were set to represent long-term relative prices in current value, which were not necessarily current prices.

Parameter	Value	Parameter	Value
Labor wage rate	$10.00/h	Selling prices	
Diesel fuel price	$0.32/L	Cull cow	$0.90/kg
Property tax rate	2.3%/yr	Calf	$20/animal
Total livestock expenses	$238/cow/yr	Milk (mailbox)	$0.27/L
Cow free-stall barn	$1000/cow	Buying prices	
Heifer free-stall barn	$625/animal	Corn grain	$125/t DM
Feed commodity shed	$70/cow	Alfalfa hay	$135/t DM
Fertilizer prices		Soybean meal	$300/t DM
Nitrogen	$0.55/kg	Protein mix	$330/t DM
Phosphorus	$0.66/kg	Mineral/vitamin mix	$350/t DM
Potassium	$0.29/kg	Straw bedding	$85/t DM
Annual cost of seed and chemicals		Replacement animals	$1600/head
New alfalfa	$200/ha	Economic life	
Established alfalfa	$15/ha	Storage structures	20 yr
Corn following other crops	$135/ha	Machinery	10 yr
Corn following corn	$165/ha	Salvage value	
Oats	$55/ha	Structures	0%
Real interest rate	6.0%/yr	Machinery	30%

The base farm represented a typical dairy farm in Pennsylvania with 100 ha of land. The soil was a loam of medium depth. Crops were rotated with 35 ha of alfalfa, 45 ha of corn, and 20 ha of oats. Alfalfa was primarily harvested as silage with some dry hay. Corn was harvested as silage to fill the available silo, and the remaining crop was harvested as high-moisture grain. Oats were harvested as high-moisture grain with the straw harvested and used as bedding. Postharvest crop yields over the 25-yr simulations averaged 10.5, 13.8, 6.3, and 2.3 metric tons of DM/ha for alfalfa, corn silage, high-moisture corn, and high-moisture oats, respectively. Alfalfa and corn silages were stored in bunker silos, and a tower silo was used for high-moisture grain.

The herd included 100 Holstein cows (lactating and nonlactating) plus replacement heifers. Replacements included 38 heifers over and 42 under 1 yr of age. Cows were milked in a double-six parlor, with annual milk production set at 10,280 kg/cow. The cow replacement rate was 35%, which was typical of that reported for herds in our DHI database. Protein needs were met with a combination of soybean meal and a less degradable protein mix. All animals were housed in free-stall barns, where floors were scraped daily. Manure was handled as slurry that was stored up to 7 mo in a concrete tank and applied to cropland.

Simulations were done for 25 yr using State College, PA, weather from 1976 through 2001. Prices were set to reflect long-term relative values of farm inputs and outputs in current dollars (Table 3). A real interest rate (approximately nominal rate minus inflation) of 6%/yr was assumed for all investments in machinery and facilities. Property tax was charged at 2.3% of the estimated assessed value of property.

Four alternative management scenarios were compared to the base farm. The first was to remove heifer production from the farm (no-heifer farm), a practice that is now used on some traditional farms. The second was to use perennial lactating cows along with the removal of heifer production. These management changes were first evaluated with the lactating herd held constant at 100 cows. A major incentive for removing heifers from dairy farms is to allow more lactating cows on the farm. Removing heifers provides more feed for cows and reduces manure nutrient production. Thus, 2 additional scenarios were simulated to evaluate these management options, with cow numbers increased to obtain similar purchased feed as that used on the base farm.

To simulate the removal of heifer production, calves were sold soon after birth and replacement animals were purchased for $1600 each as they came into production. With this option, the cost of heifer housing was eliminated. Annual livestock expenses were reduced by $40/cow to account for typical savings in the cost of heifer production (Heinrichs et al., 2000). These cost reductions included veterinary ($5/cow), breeding ($12/cow), utility ($8/cow), and miscellaneous ($15/cow) expenses. Labor requirements for animal handling were reduced by 0.2 min/cow per day (Heinrichs et al., 2000). Less forage was required, so the size and initial cost of the corn silage silo were reduced. Also, with less manure produced, the manure storage size and cost were reduced.

To model a perennial herd, animal numbers in the early-, mid-, and late-lactation groups were modified and nonlactating cows were eliminated. The cow replacement rate was set at 25%, which provided an average of 4 yr in lactation. Thus, 25 primiparous animals cycled through early and mid-lactation each year. All other animals were placed in a late-lactation group for the remaining 1300 d of lactation. Because these animals were not pregnant, their gestation energy and protein requirements were removed. Cows were assumed to have the same production potential as those in the other scenarios, which provided an average production of approximately 27 kg/d, with 26 kg/d produced by the late-lactation group. Breeding costs were eliminated and annual veterinary costs were decreased ($25/cow), reducing annual livestock expenses by $48/cow. Again, the size and cost of the corn silage silo and manure storage were reduced to accommodate fewer animals.

A more realistic evaluation of heifer removal is to increase lactating cow numbers to better utilize the feed produced. For the third alternative scenario, heifers were removed and the number of cows was increased to 120. With this number of animals, purchased feed requirements and the long-term P balance for the farm were similar to that of the base farm. The size and cost of the free-stall barn, corn silage silo, and manure storage were adjusted to accommodate the needs of the animals. All other farm parameters were the same as those used in the first no-heifer farm scenario.

For the fourth alternative, a perennial lactating herd of 128 cows was simulated. These animals required a similar amount of purchased feed as the herd in the base farm. With the change in cow numbers, the size and cost of the free-stall barn, corn silage silo, and manure storage were adjusted. All other farm parameters were the same as those used in the second alternative scenario.

Sensitivity Analyses

A number of assumptions were made that may affect the comparison between traditional and perennial dairy farms. A further analysis was done to measure the sensitivity of the simulation results to the more important assumptions or possible additional benefits for using a perennial herd. This was done by independently changing the appropriate parameters to determine the resulting change in net return relative to that of the traditional farms. Sensitivity was determined as the change in the difference in net return between the perennial cow farm (fourth alternative scenario) and the base farm due to the change in a given parameter.

An important assumption in the evaluation of a perennial dairy farm is the milk production attained from a perennial herd relative to traditional herds. Because this concept has not been implemented for a full herd, a long-term production level has not been documented. To determine the sensitivity to this assumption, production across the full lactation of a perennial herd was reduced by 5%. Thus, the average daily milk production of 26.8 kg/cow was reduced to 25.5 kg/cow. This change primarily affected milk sales with a small effect on feed use and nutrient excretion.

Another consideration is the useful life of perennial cows. The original analysis assumed an average lactation of 4 yr with 25% of the herd replaced each year. This was first compared with an average lactation of 3 yr with a 33% annual replacement rate. A shorter lactation length increased the number of animals in early lactation along with a small increase in late-lactation milk production. Based upon the daily production data in Table 1, late-lactation production was increased to obtain about 4% more milk annually. Within the model, greater production increased feed consumption (due to a greater energy requirement) and manure production. Next, the average lactation length was reduced to 2 yr with a 50% replacement rate and an 8% increase in annual milk production. For each scenario, the number of replacements purchased and cows culled increased according to the change in replacement rate.

Instead of replacing animals that fail to maintain sufficient production, the dairy manager may choose to breed the cow for another cycle. Thus, a farm may maintain a combination of animals of various lactation lengths. To quantify this effect, simulations were done with 0, 25, 50, 75, and 100% of the herd maintaining an average lactation length of 4 yr. All replacements were purchased, and animal numbers, facilities, and livestock expenses were adjusted according to the portion of each animal type on the farm.

The next 2 changes evaluated additional benefits that may be attained using a perennial herd. The first was a reduction in the mortality rate. In the original analysis, a 5% annual death loss was assumed for all cows (Smith et al, 2000). Because a high percentage of cow deaths in traditional herds involve problems at parturition or in the early postpartum period, it may be reasonable to assume a lower death loss in a perennial herd. For example, serious dystocia has been shown to account for greater numbers of deaths among first parity cows compared to later parities, with death frequencies up to 4.1% over all parities for cows with substantial dystocia complications (Dematawewa and Berger, 1997). Thus, a 4-yr perennial lactation would expose a cow to only 1 dystocia per postpartum risk compared with 3 or 4 parturitions for cows under traditional management in the same 4-yr period. The effect of lower mortality was tested by reducing the cow mortality rate from 5 to 2.5% for the perennial herd.

A second possible benefit is slightly greater average fat and protein concentrations in milk from a perennial herd. Concentrations of these components are generally greater after peak lactation. For a perennial herd where most cows are in late lactation, herd average milk fat and protein contents were predicted to be about 3% greater than those of traditional herds. Based upon current milk pricing procedures, this increase in milk solids would increase the mailbox milk price about 1%. This effect on milk price was not considered in the primary analysis, but it was included in the sensitivity analysis to determine the potential benefit of attaining this greater price.

The assumed mailbox milk price of $0.27/L may be optimistic for the future relative to the assumed costs of production. Sensitivity to overall milk price was determined by reducing the price for both traditional and perennial cow farms by 10% to give a price of $0.243/L.

Another important price is the replacement animal purchase price. A higher price may be justified to obtain replacements with the lactation persistency required for a perennial herd. To evaluate this effect, the purchase price of perennial replacements was increased to $1800/head.

RESULTS

Primary Analysis

A comprehensive evaluation of management effects on dairy farms must consider farm performance, environmental impacts, and potential profit. The 25-yr average results for our base farm and the 4 alternative scenarios are listed in Table 4. These simulation results include the feeds produced, feeds bought and sold to meet the needs of the herd, and the milk production of the herd. Nutrient balance information includes N losses to the environment and the whole-farm build up or shortage of P and K. The economic results include the production costs incurred, the income from milk, excess feed and animal sales, and the net return to management.

For the base farm with heifer production, 80% of the total feed DM requirement for the herd over the 25 yr was produced on the 100 ha land base (Table 4, column 1). Purchased feed included 61% of the grain and all of the protein and mineral supplements. With the assumed feeding strategy, a long-term P balance was maintained for the 100-cow farm. As starter fertilizer, 20 kg/ha was applied to corn land. To maintain a long-term potassium balance, 1500 kg of potash was applied each year. The farm maintained an average annual net return of $66,600. with the standard deviation in net return across years being $8,600.

Purchasing replacement animals instead of producing them on the farm (no-heifer farm) reduced forage use and the purchase of feed. With a 100-cow, no-heifer herd, corn silage production and purchased feed each decreased 50% (Table 4, column 2 vs. column 1). With this change in diet and animals fed, 24% less manure was produced with 18% less N excreted in that manure. This led to 26% less N volatilized in the barn and 18% less volatile N loss over all manure handling processes. With less manure applied to cropland, there was a 6% reduction in nitrate leaching loss and a small decrease in soil P accumulation. Production costs increased primarily due to the purchasing of replacements, which led to a $267/cow decrease in net return. On the base farm, the cost of producing heifers was about $950/head. Compared with a purchase cost of $1600/head, there was a net cost of $650 per animal purchased on the no-heifer farm.

The additional change to a perennial 100-cow herd further reduced feed requirements (Table 4, column 3 vs. column 2). Purchased protein and mineral supplements decreased an additional 52% because the requirements of the lower-producing late-lactation animals were less than those of cows with traditional management. For example, diets of perennial cows averaged 13.5% CP whereas the diets of traditional herds typically contained about 12.5, 13, 14, and 17% CP for dry-, late-, mid-, and early-lactation animals, respectively. With less protein N consumed, less N was excreted which led to lower losses to the environment. Less P was also imported in feed supplements, which decreased the farm balance of P. Reductions in purchased feed and animals provided an overall reduction in production costs. Annual net return was $220/cow less than that of the base farm, but $47/cow greater than that of the 100-cow, no-heifer farm.

Thus, removal of heifer production and use of a perennial herd each provided environmental benefit but a loss in farm profitability compared with the base farm with the same number of cows (Table 4, columns 2 and 3 vs. column 1). Compared with the traditional farm with purchased replacements (no-heifer farm), the perennial strategy provided both economic and environmental benefit (Table 4, column 3 vs. column 2). Use of the perennial herd reduced the year-to-year variation in net return or risk to the producer (Table 4) because homegrown feeds more consistently met the nutrient needs of the lower producing perennial cows.

Increasing cow numbers to better utilize the feed available on the farm when heifers were not produced provided both economic and environmental benefit relative to the base farm (Table 4, column 4 vs. column 1). With traditional management and purchased replacements (no-heifer farm), a herd of 120 cows provided a long-term P balance with 79% of their total feed requirement produced on the farm. Because heifer diets contained a greater portion of forage than lactating cow diets, this change in the number and type of animals

Table 4. Effect of purchased replacement animals and a perennial cow herd on annual feed production, feed use, nutrient balance, costs, and net return of a dairy farm in central Pennsylvania.

Production or cost parameter	Standard farm[1] 100 cows	Set farm size: No heifers[2] 100 cows	Set farm size: Perennial cows[3] 100 cows	Similar feed purchase[4]: No heifers[2] 120 cows	Similar feed purchase[4]: Perennial cows[3] 128 cows
Alfalfa hay and silage production, metric tons DM	273	273	273	273	273
Corn silage production, metric tons DM	433	219	251	321	407
Grain production, metric tons DM	100	197	180	152	112
Grain purchased, metric tons DM	157	67	61	155	177
Protein and mineral supplement, metric tons DM	40	31	15	39	25
Average milk production, kg/cow	10,280	10,280	9755	10,280	9755
Manure produced, metric ton	6200	4700	4800	5600	6000
Nitrogen lost by volatilization, kg/ha	61	50	43	53	46
Nitrogen lost by leaching, kg/ha	29	27	25	29	28
Nitrogen lost by denitrification, kg/ha	9	8	7	9	8
Phosphorus accumulation (shortage), kg/ha	0	(3)	(4)	0	0
Potassium accumulation (shortage), kg/ha	(12)	(21)	(21)	(17)	(16)
Feed production cost, $	69,800	67,300	67,600	68,700	69,500
Manure handling cost, $	15,400	12,800	13,000	14,200	15,100
Labor cost, $	38,500	34,400	34,600	40,500	43,300
Purchased feed and bedding cost, $	35,500	21,300	16,100	34,300	33,800
Animal and milking facilities cost, $	43,800	39,000	39,000	41,100	41,900
Animal purchase and livestock expenses, $	23,800	75,800	55,000	91,000	70,400
Property tax, $	5200	4800	4800	5000	5100
Total production cost, $	232,000	255,400	230,100	294,800	279,100
Milk sale income, $	269,000	269,000	255,200	322,800	326,700
Feed and animal sale income, $	29,600	26,300	19,500	29,100	22,200
Net return to management, $	66,600	39,900	44,600	57,100	69,800
SD of net return across years, $	8600	8200	7700	7600	6700

[1]100 mature cows and 80 replacement heifers on 100 ha of cropland simulated over 25 yr of State College, PA, weather.

[2]Same as standard farm except that replacement animals were purchased ($1600/head), heifer housing was eliminated, other facilities were adjusted, and annual livestock expenses were reduced by $40/cow.

[3]Perennial cows were used, all replacement animals were purchased ($1600/head), heifer housing was eliminated, other facilities were adjusted, and annual livestock expenses were reduced by $88/cow. Perennial cows had a peak milk production a few weeks after calving with a slow decline through the remainder of their productive life of 4 yr.

[4]Cow numbers were increased to obtain a similar amount of purchased feed as that used in the standard farm where replacement heifers were raised on the farm.

on the farm affected forage and grain needs. Thus, less corn silage was produced providing more corn harvested and fed as high-moisture grain. Purchased grain and protein supplements were similar to those of the base farm.

Because the additional lactating cows consumed less forage and more grain (more digestible feed) compared with the heifers they replaced, about 10% less manure was produced annually (Table 4, column 4 vs. column 1). Nitrogen content in this manure was a little greater though giving 9% less manure N excreted. Compared with the base farm, this caused 18% less N loss in the barn and 13% less volatile N loss over all manure handling processes. By design, the long-term P balance was maintained, but the need for potash fertilizer increased by 670 kg/yr.

Total production cost for the 120-cow no-heifer farm increased, with the major increase being the purchase cost of replacement animals (Table 4, column 4 vs. column 1). Labor costs also increased a small amount, which was more than offset by lower feed production, manure handling, and animal facility costs. With 20% more cows on the farm, annual milk production and the resulting income increased 20%. Still, the annual net return to farm management was $9500 less than that of the base farm.

A 128-cow perennial herd utilized a similar amount of farm-produced and purchased feed as the base farm (Table 4, column 5 vs. column 1). Less protein supplementation was required to maintain the lower daily milk production per cow in the extended late-lactation period, and therefore less N was excreted. This led to lower N losses and a similar long-term P balance compared with the base farm.

Production costs were similar to those of the 120-cow no-heifer farm except that purchased animal and livestock expenses were reduced by $20,600/yr. These expenses were less because fewer animals were purchased, breeding costs were eliminated, and veterinary costs were reduced. Annual milk production per cow

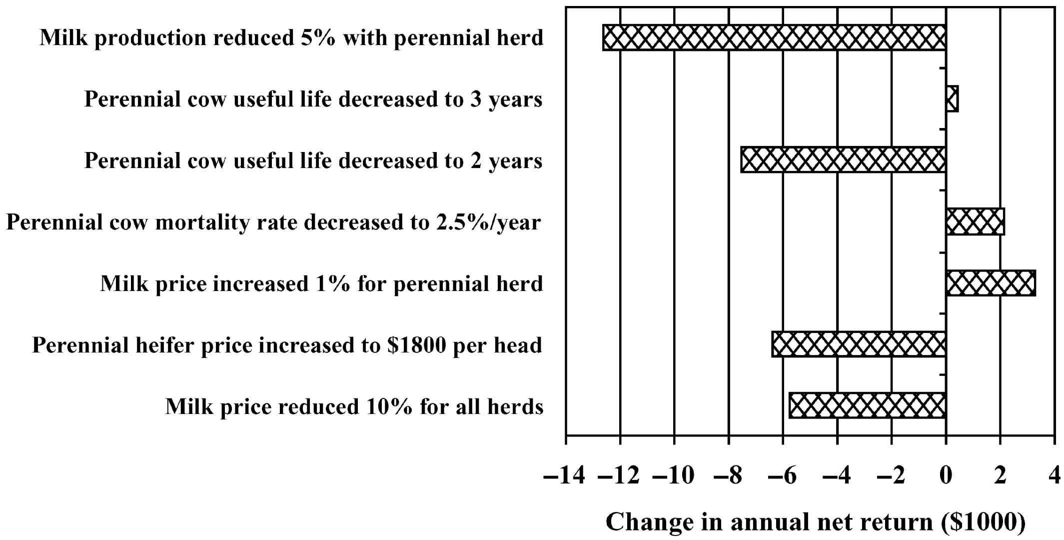

Figure 1. Effect of parameter changes on the economic benefit of a dairy farm with perennial cows and purchased replacements (Table 4, column 5) compared with a traditional dairy farm with heifers produced on the farm (Table 4, column 1).

was 5% less than that of the traditional farms. This was the combined effect of lower milk production compared with animals in early to midlactation in traditional herds and added milk from the removal of the dry period.

Overall, the 128-cow perennial herd provided an average annual net return of $69,800. This was $3200 greater than that of the base farm and superior to all the other scenarios (Table 4). This indicates an economic improvement along with an improvement in whole farm N utilization. Compared with the 120-cow no-heifer farm, the annual farm net return was $12,700 greater with small reductions in N losses (Table 4, column 5 vs. column 4). The variance in net return across years was 12 to 22% less for farms where replacements were purchased compared with the base farm. This lower variance or risk was due to a constant cost for replacements and less annual variation in purchased feed costs.

Sensitivity Analyses

Annual milk production is a critical assumption in the analysis of a perennial herd. Our original assumption was that traditional and perennial herds had the same potential production. Removing the dry period for animals with this production potential offset most of the milk lost by not having more cows in early lactation giving just 5% less milk overall. If an additional loss in production occurs with a perennial herd, the economic impact is great (Figure 1). Decreasing production an additional 5%, along with the associated reduction in feed consumption and related effects, reduced annual net return for the farm by $12,600. This change eliminated the economic benefit of using a perennial herd relative to higher-producing traditional farms with (Table 4, column 5 vs. column 1) or without (Table 4, column 5 vs. column 4) heifers produced on the farm.

The comparison of the perennial herd with the more traditional dairy production strategies was little affected by reducing the assumed average lactation length of perennial cows from 4 to 3 yr (Figure 1). With a 1-yr reduction in their average time spent in the herd along with a 4% increase in the average annual milk production, the annual net return for the farm increased by $400. A further reduction to 2 yr, however, created a substantial loss in profitability. Replacing half the herd each year was costly, reducing the annual net return by $7500.

Annual net return for the farm increased as the portion of the herd maintaining an average lactation length of 4 yr increased from 0 to 100% (Figure 2). This relationship was not linear, so a little more benefit was obtained for the first few perennial animals added to the herd than was obtained from the last few animals added to reach 100%. This implies that under the assumptions of our base analysis, maintaining any number of perennial cows in the herd provides economic benefit.

The effects of lactation length illustrated in Figure 1 indicate that an optimal length is 3 to 4 yr. For cows that are unable to maintain a suitable lactation beyond 2 yr, the most economical management strategy is to breed them for another cycle. Figure 2 implies that having a portion of the herd on a 2-yr cycle or less is

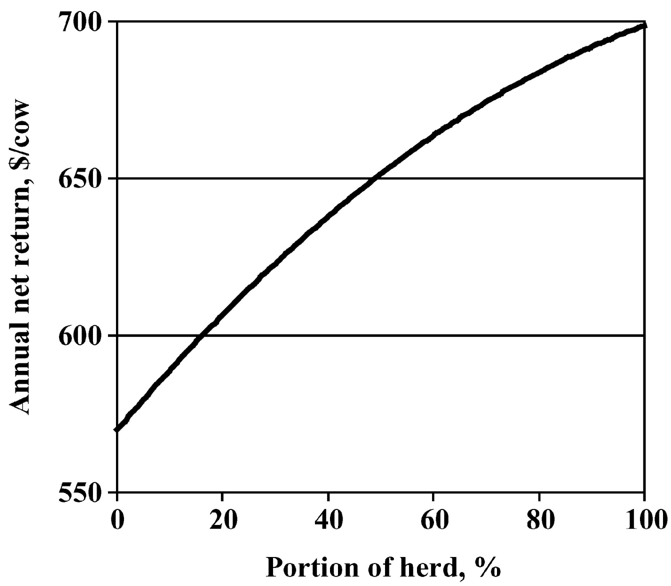

Figure 2. Annual net return for a simulated dairy farm with a varying portion of the herd being perennial cows with a 4-yr lactation.

still more economical than using traditional breeding management.

A decrease in cow mortality on the perennial farm provided a small improvement in net return (Figure 1). When the assumed cow mortality rate of 5% was halved for the perennial herd, the annual net return was increased by $2100 relative to the traditional production systems.

The fat and protein concentrations in the milk produced by a perennial herd and their potential effect on milk price were of moderate importance. When the milk price received on perennial farms was increased 1%, the annual net return was improved by $3300 relative to the traditional farms.

Replacement animal price was an important consideration in the economics of a perennial herd. If animals with this production potential cost more to purchase than traditional dairy replacements, the economic benefit for the perennial herd is reduced or eliminated. A $200/animal increase in the purchase price reduced the annual net return for the farm by $6400 for the 128-cow herd.

Milk price also can have a major impact on the feasibility of a perennial cow farm. Compared with the traditional base farm where heifers were raised, the 128-cow perennial herd produced more milk. Thus, a 10% reduction in milk price reduced the annual net return of the perennial herd by $5800 more than the reduction incurred on the traditional base farm (Figure 1). Compared with the traditional no-heifer farm, however, the perennial herd produced a similar amount of milk. Thus, a change in milk price had little effect on the comparison of these 2 scenarios (data not shown).

DISCUSSION

The results of this simulation study indicate that the concept of a perennial cow dairy farm is potentially economically feasible and also has potential environmental benefit. A key issue for maintaining economic feasibility, however, is that annual milk production per cow must be no more than 7% less than that maintained by the traditional herd to which it is compared. Although existing production records show that a small percentage of cows can maintain high production over a 4-yr lactation, it is unknown how well whole herds would perform if managed for extended lactations. Management strategies for such herds must be developed and refined with additional knowledge and experience. A perennial-cow system is not likely to be adopted by most dairy farms, but it may provide an option for some producers with an interest in specializing in this approach. The simulation results of the current study do encourage future research on the practicality of this management strategy.

One consideration is the preferred age at first calving. Ettema and Santos (2004) studied the effects of calving age of Holsteins in 3 commercial dairies. In that retrospective study, the highest economic return was derived from those calving between 23 and 24.5 mo of age, with considerations for milk production, milk components, mastitis, lameness, stillbirths, abortions, and postpartum fertility. However, to sustain a high persistence of a single lactation, it might be favorable for a freshening heifer to have more growth or maturity when she calves. Thus, the heifer would partition fewer nutrients to growth, providing more for milk production. This is an economic issue, however, as the extra months of prefreshening time would likely increase the production cost of animals entering the herd. As illustrated in the sensitivity analysis, a substantial increase in the replacement purchase price greatly reduces the economic benefit gained by using perennial lactating cows (Figure 1).

An important consideration is the optimal genetic selection and breeding strategy for the possible genetic component of sustained milk production. The database examined to attain a measure of expected production for this modeling study was derived from a report of all cows actively in production in midsummer 2003 in the national DHI files processed in Provo, UT, whose current record of production equaled or exceeded 700 d of continuous lactation. Within those records, there were 43 cows (1%) with greater than 4 yr (1460 d) of continuous lactation. Thus, there are actual cows meeting or exceeding the modeled production requirement of 21 kg/d at the 4-yr mark. When the top 16 producing cows on the last test date were isolated, the average production on that day was 27 kg (Table 1). Considering that most cows, which are impregnated in the usual period of 3 to 6 mo after calving, were unavailable for consideration for perennial lactation, it is reasonable to assume that there are many more potential cow candidates for perennial lactation.

If some dairy farms began managing for perennial lactations, cows with high lactation and long persistence would be identified and exposed to genetic evaluation. Those that perform the best in this system might be chosen as embryo donor cows and their sires would likely surface as the best male contributors to the perennial cow gene pool. Presumably, the bull families performing best now are those best suited for perennial lactation as well. At any rate, positive assortative mating could go a long way to developing this new generation of cows. Perhaps as heritability estimates for perennial lactation begin to emerge, multitrait selection indices might effectively include a component for the perennial trait. Meanwhile, it is sensible to start with breeding stock known to be genetically superior in lactation and persistence under current management. In fact, if selection indices were remodeled to embrace the perennial concept, some traits now used might drop out as no longer important. For example, cow longevity measures now used would have a markedly different context in the perennial herd.

Another consideration is biological manipulation to improve persistency for perennial cows. A recent study showed the positive effect of insulin-like growth factor I in regulating mammary gland development (Hadsell et al., 2002). This growth factor seems to slow the apoptotic loss of mammary epithelial cells during the declining phase of lactation, and early mammary gland development may be affected. Jerry et al. (2002) suggested the pathways signaling stress and stromal-mediated pathways together with p53 pathways might be used to identify animals with greater lactation persistency. A multiphasic milk production model for extended lactations may also provide new insight (Grossman and Koops, 2003). The biological basis for the model considers apoptosis and yield per cell as a function of competition from pregnancy. The model is supported with data from 3573 first-lactation Holsteins having lactations of various lengths (285, 345, 405, 465, and 525 d) and various days open (45, 105, 165, 225, and 285 d). Capuco et al. (2003) assessed persistency of lactation and reported that "Epithelial cells that stain lightly in histological sections are evident through all phases of mammary development and secretion and account for nearly all proliferation in the prepubertal gland." Characterization of these lightly staining cells could lead to techniques for enhancing epithelial cell proliferation and persistency of lactation, reduction of mastitis, and reduced dependence on a dry period to instill high lifetime production.

A less apparent benefit of perennial lactation may be improved cow husbandry or welfare. Perennial cows would have less exposure to calving problems, broken down udders, metabolic and infectious diseases incidental to the dry period and parturition time, reproductive issues, drugs and tools related to ovulation management and detection of heats, and the use of antibiotics to counter infections induced by these practices. Thus, milk and meat safety may also be improved.

Nutritional requirements for perennial lactations also are a matter of interest. Is it reasonable to conclude that the diet of cows managed in this way should be constant throughout the year? Can new feeding strategies improve the performance of perennial lactation cows? These questions highlight the need to explore new approaches to managing cows and herds where the expectations are different from the current management paradigms. The topics to be researched should include housing methods, pasture use, milk composition, milking frequency, application of bST, suppression of estrous behavior, eliminating ovulation, milk quality and safety from less antibiotic use, exercise schemes, breed differences in performance, annual production dynamics for the herd and many more aspects of perennial lactation. For example, would it be feasible to breed these perennial cows after 3 yr of lactation to recycle them into another perennial cycle?

CONCLUSIONS

A whole-farm simulation analysis illustrates that a dairy farm using perennial lactating cows can provide both economic and environmental benefits relative to traditionally managed farms, but this potential benefit is dependent upon maintaining annual milk production per cow within 7% of that of traditional farms while maintaining average lactation lengths of 3 or more years. Compared with either a traditional 100-cow dairy farm with replacement heifers produced on the farm or to a traditional 120-cow dairy farm with purchased replacements, a herd of 128 perennial cows with purchased replacements was maintained with similar feed requirements. Under the relationships used in the model, use of the perennial herd reduced purchases of supplemental protein and minerals, increased annual milk sales, reduced N losses, and increased estimated annual net returns compared to either of the traditional systems. The feasibility analysis of the perennial cow dairy farm was very sensitive to the milk production maintained by the perennial herd and the assumed market prices for milk and perennial replacement animals. The comparison to traditional farms was moderately improved by a slight increase in milk price to reflect a greater solids concentration in perennial-cow milk. The analysis was relatively insensitive to the assumed mortality rate of perennial cows and their useful life as long as they could be maintained in the herd for 3 to 4 yr. Although most of the dairy industry is expected to maintain more traditional management practices, use of a perennial lactating herd may become an appropriate option for some dairy producers with an interest in specializing in this approach. More information is needed on specific strategies to optimize management of such herds including the selection of cows that could be expected to have successful longer lactations if managed as perennial cows.

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